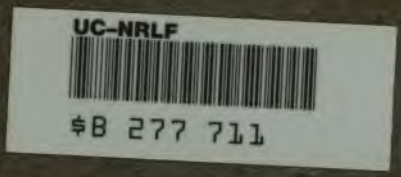


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LABORATORY EXERCISES IN STRUCTURAL AND HISTORICAL GEOLOGY

A LABORATORY MANUAL BASED ON FOLIOS OF THE UNITED STATES GEOLOGICAL SURVEY, FOR USE WITH CLASSES IN STRUCTURAL AND HISTORICAL GEOLOGY

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NEW YORK

HENRY HOLT AND COMPANY

1913

eighty-one folios have been published by the Survey, and many of them, especially the more recent ones, are well adapted to the work outlined in this manual. It is also important that these folios should be understood and used by persons other than students in schools, for they are serviceable to miners, engineers, contractors, travellers, etc., when once understood by them.

The adaptation of these outlines to fit the needs, the time, the laboratory facilities, and the amount of laboratory assistance available, must be left to the individual teacher; but two methods of presentation which have been used successfully by the authors, are suggested: (1) After the assignment of an exercise is made, the folios are placed where the students may study them at their convenience. The class is divided into sections of four, and an hour for conference with the instructor, *subsequent to the study of the folios*, is named for each section. In these conferences, the topic of the exercise is discussed informally, the folios being used for demonstration. Either before or after conference, questions so designated are answered in writing, and the papers given to the instructor for correction. (2) By the other method, definite laboratory periods are assigned, their duration and frequency being determined by the time and general plan of the course, and the degree of preparation of the students. In this case, all the work is done in the laboratory in the presence of the instructor or his assistants. The students work individually or in pairs, and receive help or criticism from the instructor on demand. The second method is the better with younger students, where time, laboratory space, assistance, and supply of folios are sufficient.

Where the program is flexible, it is better to have the laboratory work timed to fit the class-room work, rather than

on specified days. The authors hold firmly to the view that, apart from developing familiarity with very useful publications, the only functions of these laboratory exercises in geology are (1) to illustrate and emphasize the topics or principles discussed in the class-room, or (2) to introduce new topics or principles.

For a group of twenty-five students in the laboratory, three or four copies of each folio assigned are sufficient.

LABORATORY EXERCISES IN STRUCTURAL AND HISTORICAL GEOLOGY

INTRODUCTION

Topographic maps show the topographic forms resulting from the work of the various physiographic agents, such as running water, wind, ground water, glaciers, etc. From the study of these maps, some interpretation of the various processes involved in developing topography can be made with confidence. The study of geologic maps may carry the student further. Such maps show the various rock formations which appear at the surface, and the structure sections show their relations to each other, the positions of the beds if the rock is stratified, the thicknesses of the formations, and many other things to which attention is called in the exercises which follow. From these various facts about the rocks of a region, not only can the topography be interpreted more certainly than from topographic maps, but the history of the region antedating the development of the present surface can be worked out. The principles involved and their applications, are brought out in some detail in the exercises which follow.

Though the adaptation of the exercises presented in the following pages must be left to the individual teacher, the questions of each exercise are arranged for two somewhat

distinct groups of students, the one more advanced or pursuing a fuller course, and the other less advanced or pursuing a briefer course. To be more specific, students of the grade of college seniors, pursuing a course of about 120 hours in historical geology, after a thorough course in physiography, would be regarded as belonging to the first group; while students of less maturity, pursuing a course of 60 to 90 hours, would belong to the second group. As used by the authors, the complete outline of work presented herewith accompanies a course which covers Vols. II and III of Chamberlin and Salisbury's Geology. Omitting the questions marked **, the work here outlined is done by somewhat less mature students in connection with a half-year course in historical geology, based on the historical part of Chamberlin and Salisbury's College Geology.

Unless otherwise directed, students of the first group study all questions, and answer in writing those marked * and **. Students in the more elementary or briefer courses omit the questions marked **, and answer in writing those marked *. In many instances questions not marked for written answers lead up to those which are to be answered in writing; hence *all* questions should be studied in order, and studied with care. Students who have some knowledge of geologic maps at the outset, may not need the simpler exercises of the Introductory Series. Individual questions may seem to some teachers unnecessarily simple, and their answers too obvious to need attention (*e.g.*, Number 1, under Exercise II); but the experience of the authors is that some such questions are needed by the average student in the early stages of his work. There is, however, no object in dwelling on questions or ideas which are well understood.

The work here outlined should include a minimum of writing, but it should be done *with great care*. The written answers should be concise and to the point. Many of them can be given in a word or a short sentence; but in some cases, detailed explanations are called for. After his corrected paper is returned, each student should review the exercise with the folios before him, in order to see where mistakes were made.

While the deductions called for in the exercises are to be drawn chiefly from the study of the folios, reference should be made to the text-book used in the course, whenever it will be helpful.

In the study of the folios, most time should be put on the "Areal Geology" or "Historical Geology" maps; but the "Structure Section" and "Illustrations" sheets may be used where they are found in the folios, and the text of the folios may be referred to, in order to corroborate conclusions. "Surficial Geology" sheets should be given especial attention in Exercise XIII.

By observing the location in the United States of each folio studied, a good idea of the geologic history of each province of the country can be obtained during the progress of the work.

Exercises I–VI should precede the strictly historical part of the course, or accompany its very early stages. The work outlined in Exercise VII should accompany, or follow immediately, the class-room work on the Pre-Cambrian, and should be completed before work on the Cambrian is begun. The work outlined in Exercise VIII should accompany, or follow immediately the study of the Cambrian period, and be completed before the later Paleozoic periods are studied. Exercise IX might be divided into several;

but many of the principles involved were developed in connection with Exercise VIII, and the authors have found that this Exercise (IX) may well stand as a unit, and accompany the study of the later Paleozoic Systems. The assignment of this exercise is made about the time the Devonian is completed, and is finished before the Mesozoic is begun. The later exercises are used in a similar way.

It is the authors' experience that the earnest students set a high value on this work.

EQUIPMENT

Geologic Folios[1]

ALABAMA
- Gadsden
- Stevenson

ARIZONA
- Bisbee
- Bradshaw Mountains
- Clifton
- Globe

ARKANSAS
- Fayetteville
- Winslow

CALIFORNIA
- Bidwell Bar
- Big Trees

CALIFORNIA
- Colfax
- Downieville
- Lassen Peak
- Mother Lode
- Nevada City
- Pyramid Peak
- Redding
- San Luis
- Santa Cruz
- Sonora
- Truckee

COLORADO
- Elmoro
- Engineer Mountain
- Needle Mountains

[1] These folios may be obtained from the Director of the United States Geological Survey, Washington, D. C., for 25 cents per copy.

COLORADO
- Ouray
- Rico
- Silverton
- Spanish Peaks
- Telluride
- Tenmile District
- Walsenburg

DELAWARE
- Dover

DISTRICT OF COLUMBIA
- Washington

GEORGIA
- Ringgold

IDAHO
- Boise

ILLINOIS
- Chicago
- Danville

INDIANA
- Patoka

KENTUCKY
- Estillville
- London
- Richmond

MAINE
- Penobscot Bay
- Rockland

MARYLAND
- Accident–Grantsville
- Choptank
- Nomini
- Patuxent
- Pawpaw–Hancock
- St. Marys

MASSACHUSETTS
- Holyoke

MICHIGAN
- Ann Arbor
- Menominee

MISSOURI
- Joplin

MONTANA
- Fort Benton
- Little Belt Mountains
- Three Forks

NEW JERSEY
- Franklin Furnace
- Passaic
- Trenton

NEW YORK
- New York City
- Watkins Glen–Catatonk

NORTH CAROLINA
- Asheville
- Cranberry
- Mount Mitchell
- Pisgah

NORTH DAKOTA
- Bismarck
- Casselton–Fargo
- Jamestown–Tower

OKLAHOMA
- Coalgate
- Tahlequah
- Tishomingo

OREGON
- Coos Bay
- Port Orford
- Roseburg

PENNSYLVANIA
- Amity
- Beaver
- Brownsville–Connellsville
- Burgettstown–Carnegie
- Claysville
- Elders Ridge
- Elkland–Tioga
- Foxburg–Clarion
- Gaines
- Latrobe
- Masontown–Uniontown
- Mercersburg–Chambersburg
- Philadelphia
- Sewickley
- Warren
- Waynesburg

SOUTH DAKOTA
- Aberdeen–Redfield
- Belle Fourche
- Edgemont
- Elk Point
- Oelrichs
- Olivet
- Parker

TENNESSEE
- Briceville
- Greeneville
- Maynardville
- Pikeville
- Roan Mountain
- Sewanee

TEXAS
- Austin
- El Paso
- Nueces
- Uvalde

UTAH
- Tintic

VIRGINIA
- Bristol
- Fredericksburg
- Harpers Ferry
- Monterey
- Norfolk
- Pocahontas
- Tazewell

WASHINGTON
- Ellensburg
- Snoqualmie
- Tacoma

WEST VIRGINIA
- Buckhannon
- Charleston
- Franklin
- Piedmont

WISCONSIN
- Lancaster–Mineral Point
- Milwaukee

WYOMING
- Absaroka
- Aladdin
- Bald Mountain–Dayton
- Cloud Peak–Fort McKinney
- Devils Tower
- Laramie–Sherman
- Newcastle
- Sundance

A. INTRODUCTORY SERIES

Before taking up the interpretation of geologic maps, it is necessary to have a clear idea of their make-up, and of the meaning of the conventional signs on them. The geologic maps published by the U. S. Geological Survey are the standard maps of this sort for the United States, and the folios of the Survey are the principal basis for the following studies. The purpose of Exercise I is merely to introduce the beginner to geologic maps.

EXERCISE I

GENERAL FEATURES OF GEOLOGIC FOLIOS

I. ASSIGNMENT

A. Two or three of the following folios:

Cranberry, N. C.	Penobscot Bay, Me.
Engineer Mountain, Colo.	Port Orford, Ore.
Mercersburg–Chambersburg, Pa.	Roan Mountain, Tenn.
Passaic, N. J.	Sewanee, Tenn.

B. Chapters on Structural Geology in some standard text-book, as Chamberlin and Salisbury's College Geology, pp. 394–413, or Vol. I, Geologic Processes, pp. 486–525.

C. Description of Geologic Maps:

Pp. 2 and 3 *of the cover* of any folio of the U. S. Geological Survey.

Professional Paper 60, U. S. Geol. Surv., pp. 12–18.

II. OUTLINE FOR STUDY

1. Note the following points in connection with the folios assigned:

a) The number of maps, and the title of each.

b) What facts are shown on the Areal Geology Sheet (any one) and how are they shown? A thorough understanding of this sheet is necessary, as most of the work of this outline is based upon similar maps. (*Read carefully pp. 2 and 3 of the cover of a recent folio, and pp.* 12–18 *of Professional Paper* 60.)

c) What is shown on the Structure Section Sheet, in addition to what is shown on the Areal Geology Sheet?

d) Note the Illustration Sheet if the folio in hand contains one.

e) Make a brief outline of the topics considered in the descriptive text. (The texts of the folios will be used in this course chiefly to find data which cannot be read from the maps directly, or to corroborate conclusions drawn from the study of the maps.)

2. What three great classes of rocks are shown on geologic maps? Have clearly in mind the origin of each class.

3. Define system, series, formation, as applied to rock divisions, and era, period, and epoch, as applied to the divisions of geologic time.

4. Note the meanings of the various colors on the Areal Geology Sheet.

5. On the Areal Geology Sheet, note carefully the conventions (symbols) for stratified rocks; for igneous rocks; for metamorphic rocks; and for surface formations, such as glacial drift, alluvium, etc.

6. Notice that the Areal Geology Sheet shows topography,

as well as the areas where the various rock formations come to the surface.

7. How are *faults* shown on geologic maps?

8. Draw diagrams showing at least two types of *unconformity*.

9. List the geological events recorded by the diagrams in 8.

10. a) Study the legend on the Areal Geology Sheet carefully.

b) Note the chronological order of the different formations, as given in the legend (oldest at bottom of column).

11. Explain what is meant by *dip* and *strike*. How are they shown on the Areal Geology Sheet?

EXERCISE II

FOLIOS SHOWING HORIZONTAL OR NEARLY HORIZONTAL SEDIMENTARY BEDS

I. FOLIOS TO BE STUDIED

Amity, Pa.
Buckhannon, W. Va.
Charleston, W. Va.
Coalgate, Ok. (I. T.)
Elkland–Tioga, Pa.
Lancaster-Mineral Point, Wis.
Sewanee, Tenn.
Washington, D. C.
Waynesburg, Pa.

II. OUTLINE FOR STUDY

Note.—Students in more elementary and briefer courses omit questions marked **, and answer in writing questions marked *.

Students in more advanced courses study all questions, and answer in writing those marked * and **.

A. *General Questions*

*1. Draw a diagram showing how the relative ages of beds can be told by their positions with reference to one another.

2. If perfectly horizontal strata underlie a perfectly flat surface, how many formations will outcrop?

*3. a) Given a flat surface underlain by horizontal strata, each stratum 50 feet thick, in which there are valleys not more than 25 feet deep; how many strata will outcrop?

b) Given the same conditions as in a) except that the

valleys are 60 feet deep: What strata will outcrop, and in what topographic positions?

c) If the valleys are 400 feet deep, how many strata will outcrop?

*4. If strata are perfectly horizontal and uniform in thickness, what relation should there be on a geologic map between boundaries of formations and contour lines?

*5. Would the answer to 4 hold if the horizontal beds were unconformable?

**6. What are the shapes of outcrops of uniformly tilted beds on a flat surface?

**7. Explain how thickness of horizontal beds can be determined from geologic maps. Does this method involve any error if the beds have a dip?

**8. If strata have a slight dip, how can it be detected and measured from a geologic map?

B. *Questions on Folios*

Washington Folio:

*1. Compare the distribution of outcrops of the sedimentary formations (Historical Geology Sheet) with the distribution of the contours. What inference concerning the structure of these formations can be drawn from this comparison?

**2. Determine the elevation of the base of formation Nl, base and top of Nc, and the top of Ep, in the western and eastern portions of the area shown on the map. The inference?

**3. What is the thickness of Nl and Nc as shown by the Historical Geology Sheet? Considering your answer to 2, is the estimate without possible error?

4. In what ways may the varying thickness of Nc be interpreted?

5. What inference may be made from the distribution of Nl?

*6. How may the failure of Kp to underlie Nl in some places, as at Wesley Heights (2½ miles northwest of Washington) be explained?

**7. At what times was the region subjected to subaërial erosion, as shown by the relations of the formations?

Sewanee Folio:

1. Note the distribution of outcrops.

2. Note the position of the beds.

**3. Determine from the Areal Geology Sheet the thickness of formations Cw and Cl, at a point six miles north-northwest of Jasper, in the southeastern part of the area.

**4. Explain the areas of Cw surrounded by Cl. Give all conceivable explanations. Which is correct?

Charleston Folio:

**1. From the Historical Geology Sheet, determine (1) the direction of dip, and (2) as nearly as possible its amount.

Buckhannon Folio:

*1. Explain the arrangement of outcrops along the bottom of the valley of Buckhannon River.

Coalgate Folio:

*1. Determine the stratigraphic relations of formation Ng.

*2. The cause of the belted arrangement of the Carboniferous formations in the northern half of the area?

**3. Account for the varying width of the outcrops of some of these formations, notably Ct.

Elkland-Tioga Folio (Tioga Sheet):

**1. Study the distribution of outcrops east of Tioga, in relation to the distribution of contour lines. The inference? Test your conclusion by reference to the Structure Section Sheet.

Waynesburg Folio:

*1. Notice the dendritic shapes of the outcrops. The inference?

*2. Determine the elevation of the top of formation Cw at several points along the parallel of 39° 50′, and along the meridian of 80° 10′. What inference from the above?

3. Determine the thickness of formation Cw in the extreme northeast corner of the central rectangle.[1]

Amity Folio:

1. Note the distribution and shapes of the outcrops.

2. **a) Explain the outcrop of formation Cm surrounded by Cw (eastern part of central rectangle).

*b) Explain outcrops of Cg surrounded by Cw in southeast part of central rectangle.

*3. What are the stratigraphic relations of Qcm?

**4. In what direction do the strata dip?

**5. Determine, at least roughly, the amount of dip.

Lancaster-Mineral Point Folio:

1. Note the dendritic character of the outcrops.

2. Study the Areal Geology Sheet for thickness and structure of beds.

[1] The name rectangle is applied to the smallest area bounded by parallels and meridians on a map.

EXERCISE III

FOLIOS SHOWING DEFORMATION OF SEDIMENTARY BEDS WITHOUT FAULTING

I. FOLIOS TO BE STUDIED

Accident–Grantsville, Md.
Bristol, Va.
Coalgate, I. T. (Ok.)
Franklin, W. Va.
Lancaster–Mineral Point, Wis.
Newcastle, Wyo.

II. OUTLINE FOR STUDY

See *Note*, p. 11.

1. Compare the Areal Geology Sheet of the Lancaster–Mineral Point folio with the corresponding maps of the rest of the folios of the list assigned. Explain why most of the outcrops shown on the former have a dendritic arrangement, while the formations shown on the other maps outcrop in belts.

Newcastle Folio:

1. Study the cases of simple, but pronounced deformation shown by the structure sections.

2. Note the type of deformation shown by the structure sections.

Bristol Folio:

*1. Explain the belted arrangement of the outcrops.

*2. How much may be inferred from the topographic map concerning (1) the kinds of rock which underlie the region, and (2) their structure?

*3. From the Historical Geology Sheet, determine the position of the beds between Cornsville (center of west central rectangle) and Early Grove (northwest part of south central rectangle).

**4. Account for the looped outcrop of €n in the northwest rectangle.

**5. The structure of the beds in the basin of Brumley Creek, northeast rectangle.

*6. State a law for determining the direction of dip of strata from geologic maps.

*7. How may anticlines be distinguished from synclines on geologic maps?

*8. Given a formation with a dip of 20°, outcropping on a flat surface:

a) Increase the dip to 45°; does the outcrop increase or decrease in width?

b) Decrease the dip to 1°; does the outcrop increase or decrease in width?

c) If the dip becomes 90°, what relation is there between the width of the outcrop and the thickness of the formation?

*9. Given a horizontal formation outcropping on a hillside which has a slope of 20°:

a) Decrease the slope of the hill to 5°; does the outcrop increase or decrease in width?

b) Increase the slope of the hill to 60°; does the outcrop increase or decrease in width?

c) Increase the slope of the hill to 90°; what relation is there between the width of the outcrop and the thickness of the formation?

**10. Formulate a law which will express the relation between slope of surface, dip of strata, and width of outcrop.

Coalgate Folio:

*1. Explain the belted arrangement of the outcrops of the several formations.

*2. In what direction do the strata in the north part of the area dip?

*3. Why are the outcrops of Ct, Cst, Csn, etc., broader in the northeast than in the west central part of the district? Test your conclusion by reference to the Structure Section Sheet.

*4. Account for the area of Cm within Cs, east central part of map.

**5. Determine from the Historical Geology Sheet the structure of the beds northwest of North Boggy Creek (southeast part of map), along the line BB. Test your onclusion by reference to the Structure Section Sheet.

**6. Why does the outcrop of Cm disappear to the northeast of Cottonwood? If the surface rose in that direction, would there be an alternative explanation?

**7. Why is the Cb area southeast of Coalgate not connected with the Cb area to the northeast?

**8. Show by diagrams how a belted arrangement of outcrops may appear on a hillside, without a tilting of the beds.

Franklin Folio:

1. What inference as to structure may be made from the topographic map?

2. The character of Stc, as suggested by the structure sections?

*3. From the details of the eastern slope of the anticlinal mountain shown in section AA, Structure Section

Sheet, what inference may be made concerning the relative hardness of the beds?

4. Study the structure sections for the relation between the degree of folding and the amount of erosion.

*5. a) How may the looped arrangement of the Scn and Sr outcrops near Elkhorn Rock be interpreted (northeast part of Areal Geology Sheet)?

b) What does the appearance of Scn and Sr east of Mill Gap mean? (The topographic map will be of assistance in answering this question.)

**6. How are the small areas of Sl just west of the South Fork of the Potomac River in the northeast rectangle, to be interpreted?

**7. Interpret the loop-shaped outcrops of Sr northwest of Franklin.

*8. Interpret the irregular contact between the Devonian and Carboniferous outcrops in the northwest part of the map.

*9. Account for the isolated outcrop of Cpo, in Dh, directly west of Onego (N. W. rectangle).

**10. Account for the various outcrops along the line of Reed Creek (western part of central rectangle).

**11. The date of the folding of the beds of this area?

**12. Show by a series of drawings the effects of various topographic forms upon the shapes of outcrops.

Accident–Grantsville Folio:

1. Study the strip of Cpo extending in a northeast-southwest direction across the center of the Grantsville sheet:

*a) Is the formation dipping or horizontal?

b) What of the amount of dip?

**c) Determine the direction of dip by the shape of the outcrop at stream crossings, without reference to the age of the formations.

**2. Determine the structure of Dj (Grantsville Sheet) by the relations between streams and the shapes of the outcrops on either side.

EXERCISE IV

FOLIOS SHOWING DEFORMATION OF SEDIMENTARY BEDS ACCOMPANIED BY FAULTING

I. FOLIOS TO BE STUDIED

Briceville, Tenn.
Engineer Mountain, Colo.
Mercersburg–Chambersburg, Pa.
Pocahontas, Va.
Roan Mt., Tenn.
Tahlequah, I. T. (Ok.)

II. OUTLINE FOR STUDY

See *Note*, p. 11.

A. *Preliminary Questions:*

*1. Show by diagrams the difference between normal and reversed faults.

*2. Draw a diagram of a fault, and designate by letters the meaning of the following terms:

a) Fault scarp.
b) Upthrow side.
c) Downthrow side.
d) Fault plane.
e) Throw.
f) Heave.
g) Dip.
h) Hade.
i) Hanging wall.
j) Foot wall.

3. Which one of the features mentioned in 2 appears on topographic maps? The others can be studied on geologic maps, structure sections, and in the field.

*4. a) After faulting, will the upthrow or the downthrow side suffer more erosion?

b) How can the upthrow side be distinguished from the downthrow side on a geologic map?

5. Define the terms *strike-*, *dip-*, and *oblique-faults.*

**6. Show by diagram how the outcrop of a dipping bed is shifted by erosion.

7. If dipping beds are faulted, and the upthrow side is eroded more than the downthrow side, the outcrop of the dipping beds will be shifted farther in the direction of dip on the upthrow side, than on the downthrow side.

**Illustrate this point by diagram or simple maps, in the case of both dip and oblique faults.

**8. Draw a simple sketch map showing *offset with overlap.* Designate the upthrow side.

**9. Show by diagrams how outcrops may be cut out, duplicated, narrowed, and broadened, as a result of strike faults.

10. Do reversed faults occur more commonly with horizontal or with dipping beds? Explain.

B. *Questions on Folios*

Briceville Folio:

1. Are the strata horizontal or folded in the southeast part of the area? In the west and northwest parts?

*2. Locate faults on the Areal Geology Sheet.

3. Are most of the faults strike, dip or oblique faults?

*4. Are the faults normal or reversed, as shown in the structure sections?

**5. From what directions were the forces probably applied which resulted in the folding and faulting of the region?

**6. Determine as nearly as possible the date of the faulting.

Pocahontas Folio:

*1. From the Areal Sheet, work out in as much detail as possible the structure at Burke Garden, in the southwestern part of the map.

**2. What is the structure at Round Mountain (north-eastern part of south central rectangle)?

*3. What is the structure at Nye Cove, in the southwestern part of the central rectangle?

**4. Account for the sequence of outcrops along the valley of Roaring Fork, southwest of Burke Garden.

*5. What is the direction of dip of the formation Cpc, northwest of Sharon Springs, south central rectangle?

*6. Account for the juxtaposition of Cpc and €Ss in the southeastern part of the map.

7. Account for the protrusion of Devonian into Carboniferous 5 miles northeast of Effna in the south central rectangle.

**8. Explain the peculiar break in the outcrops of Sr and SDg, southeast of Effna.

9. How may the crenate outline of many of the outcrops be explained?

Tahlequah Folio:

1. What is the general structure of the formations?

**2. Explain the failure of the Devonian beds to occur between Ssc and Cbn in the small valley 2 miles north of Bunch in the south central part of the central rectangle.

3. Explain he outcrop of Ot in the valley of Barren Fork (north central part of map).

*4. Explain the isolated outcrops of Cwl and older Car-

boniferous beds in the central and north central parts of the region.

*5. Determine the downthrow side of the several faults in the western part of the area.

**6. Explain the small outcrop of Dc in the center of the northeast rectangle. Note the topographic expression of Dc.

*7. a) Which is the downthrow side of the fault cutting the small hill five miles due northeast of Wauhillan (north central rectangle)?

b) Same for the fault cutting Chl seven miles southeast of Wauhillan.

**8. Are the faults of this district probably normal or reversed? Why?

Engineer Mountain Folio:

**1. Study the faulted area in the east central part of the northeast rectangle, as follows:

a) Determine the upthrow side of each of the two faults cutting De.

b) Having determined the upthrow sides of the faults, in what direction does De dip?

c) How many periods of faulting have there been? Give dates.

d) Explain the disappearance of De and DCo to the north.

2. Determine the upthrow sides of the two faults in the southeastern part of the central rectangle.

Mercersburg–Chambersburg Folio:

*1. Which is the downthrow side of the fault in the northwestern part of the central rectangle, and the south-

eastern part of the north central rectangle, Chambersburg Areal Geology Sheet?

2. What is the direction of dip of Ꞓc and Osh?

**3. Follow the outcrop Oc along the strike from St. Thomas (southern part of northeast rectangle, Mercersburg Sheet) to the south edge of the map. Explain in detail all discontinuities.

**4. Explain the outcrop of Oc one mile southwest of St. Thomas.

**5. The fault line shown in the southwestern part of the Mercersburg sheet, running between Cove Mountain and Little Cove Creek, is in contact with several different formations in its course. Explain.

**6. Determine the amount of throw of the fault between Scy and Do (S. W. part of Mercersburg Sheet), as nearly as possible.

**7. Work out the sequence of faulting south of Mercersburg.

Roan Mountain Folio:

1. Notice the peculiar courses of the faults around Cherokee and Buffalo Mountains (west central rectangle); give possible explanations.

2. See structure sections and text for correct explanation of 1.

EXERCISE V

FOLIOS SHOWING VARIOUS PHASES OF VULCANISM

I. FOLIOS TO BE STUDIED

Elmoro, Colo.
Fort Benton, Mont.
Passaic, N. J.
Port Orford, Ore.
Spanish Peaks, Colo.
Sundance, Wyo.
Walsenburg, Colo.

II. OUTLINE FOR STUDY

See *Note*, p. 11.

A. *General Questions*

1. What are the more common igneous rocks named in the legends of these folios?

2. What is the origin of igneous rocks?

3. Name three groups of igneous rocks, classified according to the size of crystals.

*4. From the legends of the folios, choose formations in which the rocks have resulted from the cooling of intruded lava; of extruded lava. (Have in mind the relation between the rate of cooling and the size of the crystals; also the relation between the rate of cooling of extruded and intruded lavas.)

5. Explain how intrusive igneous rocks may come to be at the surface.

*6. Draw a diagram or a series of diagrams showing the

various forms assumed by igneous rocks, both intrusive and extrusive. Apply the proper geologic name to each of these forms.

**7. How may the age of igneous rocks be determined, if they are associated with stratified rocks of known age? Does the law of super-position always apply in this connection? Does it ever apply? Explain.

B. *Question on Folios*

Elmoro Folio:

1. What is the age of the igneous rock? Test the conclusions reached from the study of the Historical Geology Sheet, by reference to the Structure Section Sheet, and finally to the legend.

2. What evidence is there of erosion since the outflow of the lava?

3. Has the lava accelerated or retarded erosion? Reasons for answer.

4. What inference can be made as to the origin of the lake basins on the top of the Raton Mesa?

Walsenburg Folio:

1. Study carefully the series of dikes shown on the Igneous Geology Sheet southwest of Rouse, in the southern part of the map. Compare with the Topographic Sheet.

*2. Explain the looped outcrops of llp, elp, and bs (south central rectangle).

**3. Which is older, elp or llp, central part of central rectangle?

*4. Note the dike in the extreme south central part of the map. Which took place first, the faulting or the intrusion of the dike?

**5. If the east side of the fault mentioned under d) is the downthrow side, which way does the dike dip?

**6. What was the date of extrusion of smp relative to the faulting, and to Nn (west central part of map)?

**7. What are the relative ages of bs and Nn in the extreme west central part of the area.

Spanish Peaks Folio:

1. Determine from the Historical Geology and Structure Section sheets the dates of the volcanic activity.

2. How do the many dikes of the area affect the topography?

**3. Might the present surface relations of the Cretaceous and Eocene beds east of the mountains hold, (1) if the beds were horizontal? (2) If they dipped to the west? (3) If they dipped to the east?

**4. How has the intrusion of ad affected Eh in the southwest part of the northwest rectangle? (See Structure Section Sheet and legend.)

Port Orford Folio:

1. Note the kinds of intrusive rocks.

*2. Determine from the Areal and Structure Section sheets the age of the igneous rocks.

*3. How many times and when were the sedimentary beds of the area deformed?

**4. What hypotheses may be advanced to account for the the isolated patches of sedimentary rocks within igneous rock areas, shown on the Areal Geology Sheet? Test your theories by reference to the structure sections.

Fort Benton Folio:

1. Study the maps of this folio for examples of laccoliths and bysmaliths.

**2. Explain the curvilinear areas of igneous rock, as about Taylor Peak (south central part of map).

*3. Is the dip of the beds greater or less than the gradient of the streams on the north slope of the Little Belt Mountains?

**4. In what ways may the absence of Proterozoic (Algonkian), Ordovician, and Silurian formations be accounted for?

Sundance Folio:

1. Study the laccoliths of this region. See Areal Geology and Structure Section sheets.

Passaic Folio:

1. Note the forms of the outcrops of the igneous rocks.

**2. How could you tell, in the field, whether Trw and Trp are dikes, sills, or surface flows?

3. Study the illustrations. What causes the columns shown in Fig. 30?

EXERCISE VI

FOLIOS SHOWING METAMORPHIC ROCKS

I. FOLIOS TO BE STUDIED

Bradshaw Mountains, Ariz.	Penobscot Bay, Me.
Colfax, Cal.	Pyramid Peak, Cal.
Cranberry, N. C.	Spanish Peaks, Colo.

II. OUTLINE FOR STUDY

See *Note*, p. 11.

The processes of metamorphism should be well in mind before the study of the folios is undertaken.

A. *General Questions*

*1. What is the relation between metamorphic rocks and such diastrophic forces as those which produce folds and faults?

*2. What relation is there between vulcanism and metamorphism? See the Eh and Em formations around West Spanish Peak (Spanish Peaks folio).

*3. What sequence of events is recorded by a metamorphic formation, such as mica schist, underlying a sedimentary formation which has not been metamorphosed?

B. *Questions on Folios*

Colfax Folio:

1. Note the various kinds of metamorphic rocks shown.

*2. From the metamorphic rocks of the legend, desig-

nate one formation which is meta-sedimentary, and one which is meta-igneous.

*3. What can be said of the relative ages of sp and am? Refer to the Historical Geology Sheet and the Structure Section Sheet.

**4. What are the relative ages of sp and pr (northern part of south central rectangle)?

**5. From the Structure Section Sheet, determine the date or dates of deformation of the beds.

**6. At what time or times were the rocks metamorphosed?

7. What is the meaning of the small patches of Na just north of the American River (central and east central rectangles)?

Pyramid Peak Folio:

1. Note the various kinds of metamorphic rocks in this area.

**2. The date or dates of deformation of the beds?

**3. The probable time or times of metamorphism?

4. Is there evidence of the former greater extent of the igneous formations?

Cranberry, Bradshaw Mountains, and Penobscot Bay Folios:

1. In each of these folios, study the various metamorphic rocks shown, their relations to each other, and their relations to the igneous rocks.

**2. From the facts worked out in a), determine the dates of metamorphism in each of these regions.

B. SYSTEMIC SERIES

Having become familiar in the preceding exercises with geologic folios, and with some of the principles involved in their interpretation, and having learned to read something of geologic history from the rock record as shown on the folios, we turn to a study of the various systems of the geologic column in North America. These systems will be considered in chronological order. The study of the following exercises will result in (1) greater efficiency in the interpretation of geologic maps, (2) greater familiarity with the principles involved in the development of the many structural features shown by the maps, (3) a better working knowledge of the methods employed in reading the history of the earth from the record of the rocks, (4) an introduction to the history of the various regions of the United States in the different eras and periods of geologic time, and (5) some degree of familiarity with the general history of the earth. These exercises should emphasize the principles and facts developed in the class-room.

EXERCISE VII

ARCHEOZOIC AND PROTEROZOIC (ALGONKIAN)

I. FOLIOS TO BE STUDIED

Asheville, N. C.
Bald Mountain–Dayton, Wyo.
Bisbee, Ariz.
Cloud Peak–Fort McKinney, Wyo.
Cranberry, N. C.
El Paso, Tex.
Franklin Furnace, N. J.
Globe, Ariz.
Harpers Ferry, Va.
Holyoke, Mass.
Menominee, Mich.
Mercersburg–Chambersburg, Pa.
Needle Mountains, Colo.
Ouray, Colo.
Parker, S. D.
Passaic, N. J.
Patuxent, Md.
Penobscot Bay, Me.
Rico, Colo.
Sundance, Wyo.
Tishomingo, Ok.
Washington, D. C.

II. DIRECTIONS

In answering the questions below, most, if not all, of the above folios should be studied. If the questions cannot be answered satisfactorily from the geologic maps alone, the text of the folios should be studied. Note at the outset in which geologic province of the United States the area of each folio lies.

See *Note*, p. 11.

III. QUESTIONS

1. Outline the general distribution of the Archean and Proterozoic (Algonkian) as shown by the folios.

2. Note the kinds of rocks (see legends) in the Archean and Proterozoic (Algonkian) in each region.

3. Explain the forms of the outcrops, such as narrow belts, broad areas, etc.

4. Note the topographic positions of the outcrops.

*5. Make a comparative study of the structures and structural relations of the Archean and Proterozoic in the following regions, and illustrate with diagrams the different relationships shown:

a) New England (Holyoke and Penobscot Bay folios).

b) Piedmont Plateau (Patuxent and Washington folios).

c) Appalachian Mountains (North Carolina folios).

d) The Southern Interior (El Paso and Tishomingo folios).

e) The Northern Great Plains (Parker and Sundance folios).

f) The San Juan Mountains (Colorado folios).

g) The Bighorn Mountains (Bald Mountain–Dayton and Cloud Peak–Fort McKinney folios).

h) The Arizona Region (Globe and Bisbee folios).

*6. State briefly, but comprehensively, the geologic history recorded in each relationship shown by the above series of diagrams.

**7. State, if you can, whether or not the pre-Cambrian rocks were ever covered by later deposits in each of the regions given in 5.

8. How has vulcanism affected the pre-Cambrian rocks in the different regions? Fix the date of vulcanism as closely as possible in each case.

9. The metamorphic rocks:
   a) Date of metamorphism, if determinable?
   b) Mode of metamorphism?
   c) The antecedents of the metamorphic rocks?

*10. Work out the physical history of the Menominee region.

EXERCISE VIII

CAMBRIAN

I. FOLIOS TO BE STUDIED

A. *Folios for Elementary and Briefer Courses*

Absaroka, Wyo.
Bald Mountain–Dayton, Wyo.
Bristol, Va.
Clifton, Ariz.
Franklin Furnace, N. J.
Gadsden, Ala.
Harpers Ferry, Va.
Morristown, Tenn.
Philadelphia, Pa.
Tazewell, Va.
Tishomingo, Ok. (I. T.)

B. *Additional Folios for More Advanced Courses*

Asheville, N. C.
El Paso, Texas.
Estillville, Ky.
Fort Benton, Mont.
Greeneville, Tenn.
Holyoke, Mass.
Maynardville, Tenn.
Menominee, Mich.
Mercersburg–Chambersburg, Pa.
Needle Mountains, Colo.
Pisgah, N. C.
Rico, Colo.
Ringgold, Ga.
Rockland, Me.
Three Forks, Mont.
Tintic, Utah.

II. DIRECTIONS

Elementary Classes.—Study only the folios of group A. Study all questions, except those marked **, and answer in writing those marked *.

Advanced Classes.—Study all the folios of groups A and

B. Study all questions, and answer in writing those marked * and **. Maps of Group B are to be used especially in answering the General Questions (p. 42).

III. QUESTIONS

I. *Eastern Region*

Franklin Furnace Folio:

1. What is the general structure of the Cambrian beds?

*2. Give in detail the conditions which have caused the gap in Ch, in the extreme northwest corner of the east central rectangle.

3. What is the structure of Ch and COk in the south central rectangle?

**4. Explain in detail the distribution of Ch in the central, east central, and northeast rectangles.

*5. What causes the outcrop, and the form of the outcrop, of the Cambrian beds one mile east of Woodruff Gap, in the northwest part of the south central rectangle?

Philadelphia Folio (Norristown and Germantown Sheets):

*1. a) What is the lithological character of the Cambrian rocks?

b) Describe the geographic conditions under which these rocks were deposited.

c) The probable date of metamorphism?

2. With what other systems of rocks are the Cambrian rocks associated?

3. Note the bifurcations of faults 1 mile northeast of Radnor Station, Norristown Sheet, and ¼ mile north of Meadow Brook, Germantown Sheet.

**4. a) Draw a structure section from the final "a" of

Narcissa, south to the final "l" of Spring Mill, extreme east central part of Norristown Sheet.

b) Name the structural feature shown on the above section.

c) Outline the physical history as shown in the above structure section.

Gadsden Folio:

1. The position of the beds?

**2. With what systems do the Cambrian outcrops come in contact? Explain these contacts.

Tazewell Folio:

1. The topographic position of the outcrops?

2. Work out the structure *along the lines of the sections* (AA, BB, etc.) from the Areal Geology Sheet, then compare with the structure sections.

*3. Make a northwest-southeast structure section starting two and one-half miles north of the southwest corner of the map.

Bristol Folio:

1. Make a detailed study of the outcrops in the southeast part of the map.

*2. Make a structure section from Bristol, three miles to the northeast.

**3. Make a northwest-southeast structure section through Bristol and Tabor, from Paperville on the southeast, to the Carboniferous on the northwest.

4. Work out in detail the history of the faulted area 2½ miles northeast of Lebanon, in the northeast rectangle.

**5. Work out, with diagrams, the history which has resulted in the structure shown at the contact of Carboniferous and

Silurian west-northwest of Bristol, in the third structure section.

Morristown Folio:

1. Note the general distribution and arrangement of Cambrian outcrops.

2. Note the widths of outcrops and their variations.

3. With what other systems do the Cambrian outcrops come in contact?

4. Study the succession of Cambrian outcrops along the lines of the sections as indicated on the Areal Geology Sheet, and interpret. After the intrepretation is made, study the Structure Section Sheet.

5. What is the meaning of the shape of the northeast termini of the Cambrian outcrops near Morristown?

a) What possible interpretations?

b) Which interpretation is right?

**6. What is the structure determining the Cambrian outcrops northwest of Flat Gap near the southwest corner of the sheet?

*7. Meaning of the Cambrian extension (Cn) northeast of the town of Flat Gap, in the southwest rectangle?

**8. Meaning of the form of the Crg outcrop from Tate Springs (northwest of the center of the map) to its terminus, 6 miles or so farther east? Meaning of the abrupt terminus?

*9. Interpret the enclosed Crg outcrop at Mooresburg. (Note the form of the outcrop where crossed by the small streams.)

**10. Meaning of the Crg outcrops to the northwest of the last, including the one farthest northwest in this group?

*11. Meaning of the Sk belt in Cn, 4 miles and more south-southwest of Morristown?

*12. Meaning of the eastward extension of the Cn outcrop three miles west-northwest of Turley Mills (center of west central rectangle)?

*13. What possible interpretations may be placed upon an outcrop which varies in width from point to point? Make diagrams to illustrate.

14. What is the meaning of abrupt ends of outcrops like that of Cn just southwest of Noeton (west central rectangle)?

**15. Possible meanings of Cn outcrops near southeast corner of the sheet?

16. Meaning of the great expansion in width of Crs in the northwest part of the map?

*17. Make a northwest-southeast structure section through Noeton across the belts of Cambrian on either side.

**18. Make a similar section through Turley Mills.

**19. Near the northeast corner of the southwest rectangle, a fault line lies for a distance between Sk and Crt; traced northeast, it lies between Cm and Cn. Interpret.

**20. Note the Crs outcrops north and west of Tate Springs; note its termini in both directions. Note also its relation to other formations, and interpret.

**21. In general, how is a strike fault which crosses formations to be interpreted?

22. Note the outcrop of Crs 1½ miles southwest of Mooresburg, and its relations. What is the explanation of its presence?

23. Explain the variations in the width of Crg near Cobb Ford in the northeast part of the central rectangle.

Harpers Ferry Folio:

1. With what systems do the Cambrian outcrops come in contact?

*2. How were these contacts brought about?

3. What evidence is there that the Cambrian rocks were once more widespread than now?

Greeneville Folio:

**1. Explain fully the sequence of outcrops along the northeast-southwest fault line just east of Greeneville, in the northwest corner of the south central rectangle.

2. Explain the looped outcrop of Cn southeast of Locust Spring in the northwest corner of the central rectangle.

2. *The Interior Region*

Tishomingo Folio:

*1. The meaning of the form of the area of Cr, east of Sylvan, in the west central part of the map?

2. With what systems does the Cambrian come in contact? The explanation of the diverse juxtapositions?

3. *Western Mountain Region*

Bald Mountain–Dayton Folio:

1. What are the indications that the Cambrian once had a more extensive distribution than now?

*2. Why does Cd outcrop more extensively in the Bald Mountain quadrangle than in the Dayton quadrangle?

*3. Explain the looping of Cd to the east, where crossed by Tongue River (northeast part of west central rectangle, Dayton Sheet).

**4. Give a detailed explanation of the outcrop and the form of the outcrop of Cd, in the northeast part of the Bald Mountain quadrangle.

*5. What is the structure of Cd at Porcupine Canyon, in the west central part of the northwest rectangle (Bald Mountain Sheet)?

6. What are the stratigraphic relations of the Cambrian to the Ordovician?

**7. In the field, where would you look for the continuation of Cd, after its interruption in the southeast part of the Dayton Sheet?

Absaroka Folio (Crandall Sheet):

1. Note the position of the beds.

*2. What is the significance of the distribution of Cambrian outcrops?

3. What is the structure which gives rise to the arrangement of outcrops in valleys crossing the Cambrian?

**4. Why do not the Devonian and Carboniferous strata show on the lower part of the canyon walls down stream?

Tintic Folio:

1. Study the structure sections, and pp. 4 and 5 of the text of the folio.

Clifton Folio:

1. With what systems of rocks is the Cambrian associated, and what are its relations with each?

*2. What is the explanation of the scattered outcrops of Cc in the central and west central rectangles?

*3. Which is the downthrow side of the fault cutting Cc, one mile north of Coronado Mt., in the central rectangle?

**4. Are there two faults or three 1¼ miles south of Enebro Mountain (north central rectangle)? If two, is the earlier one a reversed or a normal fault? Explain.

4. *General Questions*

*1. What is the areal distribution of the outcrops of the system as shown by the folios?

*2. State the general character of the rocks of the system in the various regions, such as the Appalachian region, the interior, the western mountains, etc., where they outcrop.

**3. What is the position (general structure) and what the condition of the Cambrian strata and of associated igneous rocks (if any) in the several regions of outcrop?

*5. Which type of faulting is dominant in the Tennessee region?

**6. What are the economic resources of the Cambrian formations, so far as indicated by the folios?

**7. Be on the lookout for special points not included in the above general questions. Make a list of such points.

In addition to the folios listed in the exercise above, those named below also show outcrops of the Cambrian system. In localities where the Cambrian system occurs, local folios, where they exist, may be substituted for some of those listed in the exercise, or added to them.

Anthracite-Crested Butte, Colo.
Cleveland, Tenn.
Cloud Peak–Fort McKinney, Wyo.
Cranberry, N. C.
Engineer Mountain, Colo.
Hawley, Mass.
Kingston, Tenn.
Knoxville, Tenn.
Little Belt Mountains, Mont.
Livingston, Mont.
Loudon, Tenn.
Mine La Motte, Mo.
Mount Mitchell, N. C.
Nantahala, N. C.
Penobscot Bay, Me.
Pikeville, Tenn.
Pawpaw–Hancock, Md.
Rome, Ga.
Silverton, Colo.
Staunton, Va.
Sundance, Wyo.
Tenmile District, Colo.
Trenton, N. J.
Yellowstone, Wyo.

EXERCISE IX

ORDOVICIAN AND LATER PALEOZOIC SYSTEMS

I. FOLIOS TO BE STUDIED

A. *Folios for Elementary and Briefer Courses*

Aladdin, Wyo.
Bristol, Va.
Charleston, W. Va.
Cloud Peak–Fort McKinney, Wyo.
Colfax, Cal.
Danville, Ill.
Franklin Furnace, N. J.
Holyoke, Mass.
Joplin, Mo.
Latrobe, Pa.
Milwaukee, Wis.
Monterey, Va.
Morristown, Tenn.
Nevada City, Cal.
Sundance, Wyo.
Walsenburg, Colo.
Warren, Pa.
Winslow, Ark.

B. *Additional Folios for More Advanced Students*

Absaroka, Wyo.
Bidwell Bar, Cal.
Big Trees, Cal.
Bisbee, Ariz.
Burgettstown–Carnegie, Pa.
Claysville, Pa.
Downieville, Cal.
Fayetteville, Ark.
Gadsden, Ala.
Globe, Ariz.
Harpers Ferry, Va.
Lassen Peak, Cal.
Lancaster–Mineral Point, Wis.
London, Ky.
Mother Lode, Cal.
Needle Mountains, Colo.
Oelrichs, S. D.
Patoka, Ind.
Pawpaw–Hancock, Md.
Piedmont, W. Va.
Pikeville, Tenn.
Pyramid Peak, Cal.
Redding, Cal.
Rockland, Me.
Silverton, Colo.
Stevenson, Ala.
Tishomingo, Ok., (I. T.)

II. OUTLINE FOR STUDY

Note.—See DIRECTIONS, p. 35.

1. *The Interior Region*

Danville Folio:

*1. Explain the distribution of Carboniferous outcrops.

*2. What inference can be made from the outcrops as to the position of the Carboniferous strata?

*3. Compare the elevation of the upper surface of the Carboniferous at the heads of the several valleys. Interpret.

**4. Could there be more than one explanation for the discontinuous outcrops of Carboniferous along Vermilion River?

5. Study the columnar sections following the maps.

Patoka Folio:

1. Explain the general distribution of the Carboniferous outcrops.

**2. Account for the failure of Cd to outcrop between Cs and Ci on certain hill slopes, as near Erskine, southwest part of the map.

Milwaukee Folio:

1. Note the character of the Paleozoic rocks.

**2. What is the explanation of the isolated outcrops of Silurian and Devonian rocks scattered over the area?

**3. Why is the Devonian confined to the northeast part of the region?

Joplin Folio:

*1. Why do so few formations appear in this region?

**2. Explain the fact that Cc does not occur under Cck in Secs. 14 and 23, Twp. 28 N., R. 31 W., in view of the fact

that it does outcrop just south of here, in Secs. 23 and 26. Note the ages of the beds involved.

Winslow Folio:

*1. What is the explanation of the recurrence of beds (as Chl) in the valley bottoms?

2. Can an unconformity between the Mississippian and the Pennsylvanian be detected on the map?

**3. At Cove Creek in the west central part of the map, two faults cross each other. Is it possible that they are contemporaneous? If not, what can be concluded as to the amount of dip of the earlier one?

Tishomingo Folio:

**1. Make a structure section from Mill Creek (northwest part of map) due southwest to the outcrop of €sa.

Fayetteville Folio:

**1. Explain in detail the distribution of Carboniferous outcrops four miles east of Johnson, in the northwest part of the southeast rectangle.

**2. Account for the Devonian outcrops in the northern part of the southwestern rectangle.

2. *Cumberland–Alleghany Plateau Region*

Charleston Folio:

*1. What is the general structure in this region?

**2. Explain the outcrops of Cs in certain valleys in the south central rectangle.

*3. Explain the isolated outcrops of Cbx east of Charleston.

4. Study the relations of the Lower Carboniferous to the Carboniferous, as shown on the Columnar Section Sheet.

Latrobe Folio:

1. Study in detail the outcrops along the line of Chestnut Ridge.

2. What is the meaning of the Cm patches within Ccm, northwest central part of map?

3. What is the meaning of the Ccs outcrop within Ccm to the east of Nihil in the northwest part of the map?

3. *The Appalachian Region*

Warren Folio:

1. Note the general character and structure of the Paleozoic strata.

2. Notice especially the texture of the Carboniferous beds.

**3. a) Account for the juxtaposition of Cpo and Ck at several points in the east central part of the area.

b) Determine the thickness of Cch in the eastern part of the sheet.

c) What is the minimum amount of post-Mississippian pre-Pennsylvanian erosion?

d) Give some idea of the time represented by this unconformity.

*4. Explain the failure of Cps and Cpo to appear between Cch and Cpc in the east central part of the area. Take into consideration the lithological character of the formations involved.

Monterey Folio:

**1. Has folding or faulting been the more important factor in determining the arrangement of outcrops?

**2. Explain the isolated outcrops of Cpo in the north central rectangle.

*3. What striking difference is there between the structure of this region and that of the Morristown quadrangle?

*4. Explain the concentric arrangement of outcrops with Sj in the center, near the eastern border of the south central rectangle.

*5. From the data given on the map, what inference can be drawn concerning the age of the igneous outcrops in the northeast rectangle?

6. Is there more than one possible explanation for the distribution of igneous outcrops shown in the northeast rectangle?

7. Note the structural positions of the valleys in the different parts of the map.

8. What is the structure of the high points?

Bristol Folio:

1. Compare the attitude of the Silurian and Devonian beds with that of the Carboniferous beds.

**2. Explain the distribution of the outcrops of Sa in the southeast portion of the map.

**3. Study the contact of the Carboniferous, in the northwest part of the map, with the formations to the southeast. Follow this contact across the sheet, and determine the structure which occasions the various outcrops.

*4. Explain the isolated patches of Cnr and Cws in the northwest corner of the map.

**5. Explain the distribution of the Devonian outcrops, Dc and Dcg.

*6. Why is there so little Devonian at the surface?

*7. Why are the outcrops of Devonian narrower here than in the Monterey region?

8. Why are there no Carboniferous outcrops in the southeast part of the area?

9. What is the meaning of the outcrop marked SDh, through the central portion of the map?

10. Determine the downthrow side of the faults just west of Ravens Nest, central rectangle.

11. Note the relation of drainage to structure.

Franklin Furnace Folio:

*1. Explain the interruption of Oj, 1½ miles north of Lafayette, in the west central rectangle.

*2. Explain the offset in Oj in the north central part of the central rectangle. How does this differ from the fault in 1?

**3. Work out the history of the Ordovician outcrops in the northwest part of the west central rectangle.

4. *The New England Region*

Holyoke Folio:

1. What general structure is suggested by the arrangement of outcrops in the southwest rectangle?

*2. Explain the form of the Sg outcrop in the west central rectangle, including the peculiarity of outcrop at the westernmost crossing of the Westfield River.

**3. How would you go to work in the field to determine the age of the Cw formation? Designate the most important or most favorable places to visit.

**4. What possible explanations can be given, from a study of the Historical Geology Sheet, for the present distribution of Cw outcrops?

**5. How would you go to work in the field to determine whether Cw is intrusive or extrusive?

*6. Account for the outcrop of Sg in the north central and northwestern rectangles.

5. *East Base of Rocky Mountains*

Walsenburg Folio:

This may be regarded as a type of the Carboniferous outcrops at the east base of the Rocky Mountains. Study its general features.

Aladdin Folio:

1. What feature occasions the intricate outcrops in the southwest corner of the sheet?

*2. From the Areal Geology Sheet, determine the nature of the chief feature at Sheep Mtn. Test your conclusion by the structure section sheet.

Sundance Folio:

*1. What is the structure of Bear Lodge Mountains in the northwest corner of the area?

**2. What data were used in mapping Green Mtn., Bald Mtn., and Strawberry Mtn. as laccoliths on the structure section sheet?

3. From the structure section sheet, what can be said of the date of vulcanism north of Cement Ridge?

6. *The Rocky Mountain Region*

Absaroka Folio (Crandall Sheet):

**1. What are the possible ways of explaining the present arrangement of Devonian and Carboniferous outcrops? Study especially in this connection the Sunlight Basin in the east central rectangle. Why does not Cambrian appear in this rectangle?

**2. Work out the physical history of the region where the Carboniferous and Devonian appear.

Cloud Peak–Fort McKinney Folio:

*1. What is the date of the faulting at Bald Ridge, just west of the Fort McKinney Military Reservation?

**2. Explain the failure of the Paleozoics to outcrop along the Archean in two places northwest of Buffalo.

Needle Mountains Folio:

**1. Work out the sequence of the faulting in the northeast corner of the northwest rectangle. On the basis of but three faults, is the first one reversed or normal?

Silverton Folio:

**1. Work out the physical history of this region to the close of the Paleozoic.

7. *The Arizona Region*

Globe Folio:

**1. Make a structure section from the letter "B" in the name "Granite Basin" (northwestern part of map), northeast to the letter "B" in the name "Ruin Basin."

2. Work out the structure along the section line AA from the Areal Geology Sheet, and then compare it with the structure section.

Bisbee Folio:

1. Work out in as great detail as possible the history of the faulted area about Bisbee. The fault-diagram sheet will be helpful.

**2. Study the structure sections and interpret the physical history of the region.

8. *The California Region*

Colfax Folio:

**1. What has been the chief factor in determining the present form and distribution of Carboniferous outcrops? Note their topographic position.

2. From the structure sections, notice the various formations with which the Carboniferous comes in contact.

*3. What was the character of the topography of the region at the time of the Na flows?

Nevada City Special Folio:

Note the scale, contour interval, and great detail of this map.

*1. How may the present outcrops of Carboniferous be accounted for?

2. From the sections, determine with what formations the Carboniferous comes in contact in this region.

3. What is the condition of the Carboniferous rocks in this region?

**4. From the structure sections, can any generalization be made as to the location of the ore veins?

5. Note the location of the auriferous gravels and their positions relative to the present drainage lines.

General Questions on the California Region

**1. What is the general geographic location of the areas shown on the folios?

**2. Which of the several Paleozoic systems appear in this region?

**3. What is the condition of the Paleozoic formations in this region?

**4. With what other systems do the Paleozoic beds come in contact?

**5. How, in general, may the present outcrops of Paleozoic rocks be accounted for?

6. Note the contacts of the Carboniferous in the Pyramid Peak folio.

General Questions on the Ordovician, Silurian, Devonian, and Carboniferous Systems

1. Compare the positions of the Ordovician, Silurian, Devonian and Carboniferous strata in the different regions.

**2. What changes in structure occur in passing from north to south in the Appalachians?

*3. Compare the relative areas of outcrop of the Silurian, Devonian, and Carboniferous formations in each region.

4. What are the relative thicknesses of the Silurian, Devonian, and Carboniferous formations in each region?

**5. What structure prevails at the west or northwest border of the Appalachian Mountain belt?

**6. Compare the outcrops of Devonian in Maryland and West Virginia with those in eastern Tennessee and Alabama.

*7. Does the same type of faulting prevail in all parts of the Appalachian Mountains? Note the location as well as the fact of variations, if such occur.

*8. Where is faulting and where is folding the more important?

**9. What are the ages of the igneous rocks associated with the Paleozoic strata in the various regions?

*10. In which region has vulcanism most affected the Paleozoic systems?

11. What kinds of rock represent the different Paleozoic periods in the various regions?

The folios listed below also show outcrops of the later Paleozoic systems, and they may be used, if a more extended course is desired; or, folios of local interest may be substituted for some of those listed above, or added to them.

Amity, Pa.
Anthracite–Crested Butte, Colo.
Asheville, N. C.
Atoka, Ok. (I. T.)
Bald Mountain–Dayton, Wyo.
Beaver, Pa.
Briceville, Tenn.
Brownsville-Connelsville, Pa.
Buckhannon, W. Va.
Chattanooga, Tenn.
Chicago, Ill.
Cleveland, Tenn.
Clifton, Ariz.
Coalgate, Ok. (I. T.)
Columbia, Tenn.
Cottonwood Falls, Kas.
Ditney, Ind.
Ebensburg, Pa.
Edgemont, S. D.
Elders Ridge, Pa.
Elkland–Tioga, Pa.
El Paso, Texas.
Estillville, Ky.
Foxburg–Clarion, Pa.
Fort Benton, Mont.
Franklin, W. Va.
Gaines, Pa.
Greeneville, Tenn.
Hartville, Wyo.
Hawley, Mass.
Huntington, W. Va.
Independence, Kas.
Indiana, Pa.
Jackson, Cal.
Johnstown, Pa.
Kingston, Tenn.
Kittanning, Pa.
Knoxville, Tenn.
Laramie–Sherman, Wyo.
Little Belt Mountains, Mont.
Livingston, Mont.
Loudon, Tenn.
Masontown–Uniontown, Pa.
Maynardville, Tenn.
McMinville, Tenn.
Mercersburg–Chambersburg, Pa.
Mount Stuart, Wash.
Muskogee, Ok. (I. T.)
Newcastle, Wyo.
New York City, N. Y.
Ouray, Colo.
Passaic, N. J.
Pocahontas, Va.
Penobscot Bay, Me.
Pikes Peak, Colo.
Placerville, Cal.
Raleigh, W. Va.
Richmond, Ky.
Rico, Colo.
Ringgold, Ga.
Rogersville, Pa.
Rome, Ga.
Rural Valley, Pa.
Sacramento, Cal.
Sewanee, Tenn.
Sewickley, Pa.
Smartsville, Cal.

Snoqualmie, Wash.
Sonora, Cal.
Standingstone, Tenn.
Staunton, Va.
Tahlequah, Ok. (I. T.)
Tazewell, Va.
Tenmile District, Colo.
Three Forks, Mont.
Tintic, Utah.
Wartburg, Tenn.
Watkins Glen–Catatonk, N. Y.
Waynesburg, Pa.
Yellowstone, Wyo.

EXERCISE X

TRIASSIC AND JURASSIC

I. FOLIOS TO BE STUDIED

A. *Folios for More Elementary and Briefer Courses*

Belle Fourche, S. D.	Philadelphia, Pa.
Holyoke, Mass.	Pyramid Peak, Cal.
Laramie–Sherman, Wyo.	Roseburg, Ore.
Ouray, Colo.	Tenmile District, Colo.
Passaic, N. J.	Trenton, N. J.

B. *Additional Folios for More Advanced Courses*

Aladdin, Wyo.	Harpers Ferry, Va.
Bald Mountain–Dayton, Wyo.	Mother Lode, Cal.
	Mount Mitchell, N. C.
Colfax, Cal.	Redding, Cal.
Cranberry, N. C.	Rico, Colo.
Devils Tower, Wyo.	Sonora, Cal.
Edgemont, S. D.	Telluride, Colo.
Engineer Mountain, Colo.	Truckee, Cal.
Fort Benton, Mont.	

II. OUTLINE FOR STUDY

Note.—See DIRECTIONS, p. 35, and *Note*, p. 11.

1. *Eastern United States*

Holyoke Folio:

1. Can the existence of a fault along the west margin of the Jura-Trias be determined from the Historical Geology Sheet? See the Structure Section Sheet.

2. Note the various sorts of igneous rocks associated with the Jura-Trias.

**3. What inference can be drawn from the shape of the outcrop of the Holyoke diabase? Carry this inference to details.

*4. How might it be determined in the field whether or not the two southern exposures of Jhp (east part of south central rectangle) are parts of the same lava bed?

**5. a) Can it be told from the Historical Geology Sheet whether Jhp in the south central rectangle is a dike, or an interbedded lava sheet?

b) How might it be determined in the field?

c) If Jhp is a sheet, how may it be determined whether it was intrusive or extrusive?

6. The relative age of Jhp and Jb, in the east central rectangle?

7. Study the relations of the various sorts of igneous rocks to one another, and to the sedimentary rocks, as shown by the Structure Section Sheet.

Passaic Folio:

1. Note the geographic and physiographic location of this area.

2. Note the contact of the Triassic with older rocks in the northwest part of the area.

*3. How would you determine in the field whether or not the contact of the Triassic with older rocks is a fault contact?

4. How have the igneous outcrops influenced the topography of the region?

**5. Explain the hooked outcrops of Trw.

6. The age of Trw and Trp?

**7. a) Can it be told from the Areal Geology map whether

Trw, is in the form of dikes or interbedded lava sheets?

b) How might it be determined in the field?

c) If Trw is a sheet, how may it be determined whether it was intrusive or extrusive.

Trenton Folio:

1. Note (a) the character of the Triassic igneous rocks, and (b) their relation to the sedimentary rocks.

*2. Does the areal geology sheet (including legend) show whether the igneous rocks were intrusive or extrusive? If so, how?

3. Note the influence of the several members of the Triassic system on the topography.

Philadelphia Folio:

*1. Account for the juxtaposition of Trs with older beds of varying ages on the Norristown and Germantown sheets.

2. Explain the isolated outcrops of Trs in the southwest corner of the central rectangle, Norristown sheet.

**3. How did the author of the folio know that the diabase dikes were Triassic?

2. *The Western Interior Region*

Belle Fourche Folio:

1. Note the location of this quadrangle with reference to the Black Hills uplift.

*2. Work out the early Mesozoic history of the quadrangle from the lithologic characteristics and the structural and stratigraphic relations of the Spearfish and Sundance formations.

Tenmile Folio:

*1. What structure could give rise to the peculiar relation

of sedimentary and igneous rock outcrops shown on the economic geology sheet?

2. Study the two Structure Section sheets.

3. Do the structure sections afford the data necessary for determining whether the igneous rock is intrusive or extrusive?

3. *The Rocky Mountain Region*

Ouray Folio:

1. Notice the stratigraphic and structural relations of the Triassic and Jurassic formations.

**2. Draw a structure section from Baldy Peak, in the west central rectangle, southwest to the edge of the sheet.

*3. Determine the age of the east-west fault immediately south of Ouray.

**4. Interpret the relation of Tqm to the early Mesozoic formations, southwest of Ouray.

Rico Folio:

1. What inference concerning the structure may be drawn from the arrangement of the Triassic and Jurassic formations?

**2. Give the physical history of this region during the early Mesozoic time.

**3. Is the Thm, near the south border of the quadrangle, intrusive or extrusive? Reasons for your answer?

Laramie–Sherman Folio:

1. Note the location of the area.

*2. Explain the absence of the Sundance formation in the Laramie quadrangle, and its presence in the Sherman quadrangle.

*3. a) What field evidence would you use to prove the presence or absence of Permian in the Chugwater formation?

b) If the lower Chugwater beds are of Permian age, what are the stratigraphic relations of the Permian beds of the region?

c) Judging from this folio, would the Permian better be classed with the Paleozoic or the Mesozoic?

Fort Benton Folio:

1. How are the peculiar outcrops of Je in the southeastern part of the map, at Skull Butte and southwest of Skull Butte, to be interpreted?

4. *The Pacific Coast*

Pyramid Peak Folio:

Study the structure sections and compare them with the Areal Geology Sheet, especially for the relation of igneous rock to the Jura-Trias. (The Mother Lode, Colfax, and Sonora, Cal., folios show similar conditions.)

Redding Folio:

**1. Work out the early Mesozoic history of the region from a study of the relations of the beds and their lithology.

2. Explain the peculiar shape of the Trh outcrops in the east central and northeast rectangles.

Roseburg Folio:

1. Note the relations of the Jr outcrops to the other formations in the southwest rectangle. The possible interpretation of these outcrops?

5. *General Questions on the Triassic and Jurassic (Jura-Trias)*

**1. Compare the structural conditions of the Jura-Trias strata in the different regions.

*2. Compare the structure of the Jura-Trias of the East with the structure of the Paleozoic of the Appalachians.

*3. Compare the structure of the Jura-Trias of the West with that of the Paleozoic of the West.

**4. What are the different factors determining the forms of the outcrops in the various regions?

*5. What kinds of rocks represent the Jura-Trias in the different regions?

**6. What kinds of rocks have resulted from contact metamorphism?

7. To what distances, as shown on the maps, has contact metamorphism affected the clastic formations?

**8. What economic products are found in or associated with the Jura-Trias formations, in the areas represented by the folios?

**9. The relations of the Jura-Trias sedimentary beds to igneous rocks.

a) In the East.

b) In the West.

The following folios may be used for a more extended study of the Triassic and Jurassic systems, or for substitution in the list given in the exercise above:

Anthracite–Crested Butte, Colo.
Bidwell Bar, Cal.
Cloud Peak-Fort McKinney, Wyo.
Downieville, Cal.
Hartville, Wyo.
Jackson, Cal.
La Plata, Colo.
Lassen Peak, Cal.
Little Belt Mountains, Mont.
Marysville, Cal.
Monterey, Va.
Newcastle, Wyo.
New York City, N. Y.
Oelrichs, S. D.
Patuxent, Md.
Pikes Peak, Colo.
Pisgah, N. C.
Pueblo, Colo.
San Luis, Cal.
Santa Cruz, Cal.
Three Forks, Mont.
Walsenburg, Colo.
Yellowstone, Wyo.

EXERCISE XI

COMANCHEAN AND CRETACEOUS

I. FOLIOS TO BE STUDIED

1. *The Atlantic Coast*

Dover, Del.
Fredericksburg, Va.
Passaic, N. J.
Patuxent, Md.
Trenton, N. J.
Washington, D. C.

2. *Texas*

Austin
El Paso
Nueces
Uvalde

3. *The Great Plains*

Aberdeen–Redfield, S. D.
Aladdin, Wyo.
Belle Fourche, S. D.
Bismarck, N. D.
Devils Tower, Wyo.
Jamestown–Tower, N. D.
Laramie–Sherman, Wyo.
Olivet, S. D.
Parker, S. D.
Sundance, Wyo.

4. *The Rocky Mountains*

Bald Mountain–Dayton, Wyo.
Cloud Peak–Fort McKinney, Wyo.
Elmoro, Colo.
Engineer Mountain, Colo.
Little Belt Mountains, Mont.
Rico, Colo.
Spanish Peaks, Colo.
Telluride, Colo.

5. *The Pacific Coast*

Colfax, Cal.
Coos Bay, Ore.
Lassen Peak, Cal.
Roseburg, Ore.

II. DIRECTIONS

Elementary and Briefer Courses.—Study enough of the folios of each region listed above to enable you to answer the questions marked *, in the outline below.

Advanced Courses.—Study all the folios listed above, and answer in writing questions marked * and **. Study the texts as well as the maps of the folios, wherever it is necessary to answer the questions fully.

Note.—See *Note*, p. 11.

III. QUESTIONS

*1. What are the stratigraphic relations of the Cretaceous beds to the overlying and underlying formations in the different regions, so far as shown in the folios?

**2. Prepare diagrams illustrating the structural conditions of the Cretaceous and associated strata in the different regions.

*3. What are the factors determining the general forms of the outcrops of Cretaceous in the different regions?

*4. Prepare one large diagram, or a series of smaller diagrams, illustrating all the ways in which igneous rock is associated with the Cretaceous.

**5. What is the age of the igneous rock associated with the Cretaceous in the different regions, and how is this age determined?

*6. What kinds of rock represent the Cretaceous system in the different regions?

**7. What, if any, products of economic value do the Cretaceous formations contain, as shown in the folio maps?

*8. Determine as closely as possible from the folios, the date of origin of the Rocky Mountains. Read especially in

this connection the description of the Kingsbury conglomerate, p. 8, Bald Mountain–Dayton folio.

The following folios may also be used to illustrate the Comanchean and Cretaceous systems:

Alexandria, S. D.
Anthracite–Crested Butte, Colo.
Atoka, Ok. (I. T.)
Edgemont, S. D.
Elk Point, S. D.
Fort Benton, Mont.
Hartville, Wyo.
La Plata, Colo.
Livingston, Mont.
Mitchell, S. D.
Mother Lode, Cal.
Nepesta, Col.
Newcastle, Wyo.
New York City, N. Y.
Oelrichs, S. D.
Ouray, Colo.
Philadelphia, Pa.
Pikes Peak, Colo.
Placerville, Cal.
Port Orford, Ore.
Pueblo, Colo.
Redding, Cal.
San Luis, Cal.
Santa Cruz, Cal.
Tishomingo, Ok. (I. T.)
Three Forks, Mont.
Truckee, Cal.
Walsenburg, Colo.
Yellowstone, Wyo.

EXERCISE XII

TERTIARY

I. FOLIOS TO BE STUDIED

A. *Folios for More Elementary and Briefer Courses*

Aladdin, Wyo.
Bald Mountain-Dayton, Wyo.
Bismarck, N. D.
Bradshaw Mountains, Ariz.
Choptank, Md.
Cloud Peak–Fort McKinney, Wyo.
Devils Tower, Wyo.
Dover, Del.
Needle Mountains, Colo,
Ouray, Colo.
Patuxent, Md.
Philadelphia, Pa.
Rico, Colo.
Snoqualmie, Wash.
St. Marys, Md.
Sundance, Wyo.
Trenton, N. J.

B. *Additional Folios for More Advanced Courses*

Absaroka, Wyo.
Big Trees, Cal.
Boise, Idaho.
Colfax, Cal.
Coos Bay, Ore.
Downieville, Cal.
Elk Point, S. D.
Little Belt Mountains, Mont.
Mother Lode, Cal.
Nevada City, Cal.
Nomini, Md.
Richmond, Ky.
Roseburg, Ore.
San Luis, Cal.
Santa Cruz, Cal.
Tacoma, Wash.
Walsenburg, Colo.
Washington, D. C.

II. DIRECTIONS

Elementary Course.—Study the folios of Group A above. Omit the General Questions. Prepare answers to all questions except those marked **, and answer in writing questions marked *.

Advanced Course.—Study all the folios of A and B above, using those of Group B especially for answering the General Questions. The folios should be studied with particular care, the structure sections and texts being used freely. Answer in writing questions marked * and **.

Note.—See *Note*, p. 11.

III. QUESTIONS

1. *The Atlantic Coast*

Patuxent, St. Marys, Dover, Philadelphia, Choptank, and Trenton Folios:

*1. What conclusions concerning the physical geography of the Eocene period can be drawn from the character of the Eocene rocks?

**2. State the history of the Tertiary in the region from the description of the Tertiary system. For details, read the sections on Historical Geology in the folios.

2. *Black Hills and Great Plains*

Aladdin, Devils Tower, Sundance, and Bismarck Folios:

*1. What was the date of deformation of the Black Hills? Reasons.

**2. The relative ages of deformation and igneous activity?

3. What forms were taken by the igneous rocks?

*4. Give in detail the events that led up to the formation of Devils Tower (Devils Tower folio).

5. *Elk Point Folio:*

**a) Is there any suggestion of a more extensive distribution of the Tertiary than is shown on the map?

**b) What would be the basis for conclusions concerning such changes of drainage as those described in the History of the Tertiary? (See text of folio.)

3. *The Bighorn Mountains*

Cloud Peak–Fort McKinney and Bald Mountain–Dayton Folios:

*1. From the geologic map, determine as closely as may be the age of the Bighorn Mountains.

2. Read the descriptions of the Tertiary formations in the texts of the folios, noting:

a) The character of the beds.

b) Their topographic position.

c) Their stratigraphic relations.

**d) Read "Age and Origin," p. 9, Cloud Peak-Fort McKinney Folio. What would you say of the probability of the glacial origin of these beds?

4. *The San Juan Mountains*

Needle Mountains, Ouray, and Rico Folios:

**1. Name the chief events of the Tertiary period in chronological order.

**2. What is the relation of the deformation to the ore deposits? Which epoch of deformation is involved?

*3. From the Rico Areal Geology Sheet, determine the relative ages of the igneous activity and the faulting.

4. Compare the San Juan uplift with the main area of the Rocky Mountains, as to

a) Character of deformation.

b) Date of deformation.

*5. What are the stratigraphic relations of the Telluride conglomerate?

5. *The Cascade Mountains*

Snoqualmie Folio:

**1. Describe the geographic conditions of the early Eocene.

*2. What was the chief event of the Tertiary period?

6. *Arizona*

Bradshaw Mountains Folio:

*1. Of what rocks is the Tertiary system composed?

**2. How were the ores deposited?

3. The age of the ores?

7. *The Coast Ranges*

Santa Cruz Folio:

**1. List the principal events of this region during the Tertiary period. Include geographic changes, diastrophic events, and igneous activity.

8. *General Questions on the Tertiary*

**1. Adapt the general questions on the Cretaceous (p. 62), to the Tertiary formations, noting the following:

a) Study in detail (reading text) the Nomini, Washington, Richmond, Tacoma, and San Luis folios.

b) In connection with the stratigraphic relations of the Tertiary beds, study the columnar sections in the more recent folios.

c) In connection with the igneous rocks associated with the stratified Tertiary formations, study particularly the following folios: Ouray and Walsenburg, Colo., Absaroka, Aladdin, Devils Tower, and Sundance, Wyo.,

Little Belt, Mont., Bradshaw Mountain, Ariz., Boise, Idaho., Big Trees, Nevada City, Santa Cruz, Colfax, Downieville, Mother Lode, Cal., and Roseburg and Coos Bay, Ore.

In addition to the maps listed above, the following folios also show Tertiary formations, and should be used if more extended study is desired:

Anthracite–Crested Butte, Colo.
Austin, Texas.
Bidwell Bar, Cal.
Butte Special, Mont.
Camp Clarke, Neb.
Coalgate, Ok. (I. T.)
Edgemont, S. D.
Ellensburg, Wash.
Elmoro, Colo.
Fort Benton, Mont.
Fredericksburg, Va.
Globe, Ariz.
Harpers Ferry, Va.
Hartville, Wyo.
Huntington, W. Va.
Jackson, Cal.
La Plata, Colo.
Laramie–Sherman, Wyo.
Lassen Peak, Cal.
Livingston, Mont.
Marysville, Cal.
Mount Stuart, Wash.
Nampa, Idaho.
Nepesta, Colo.
Oelrichs, S. D.
Patoka, Ind.
Pawpaw–Hancock, Md.
Pikes Peak, Colo.
Port Orford, Ore.
Placerville, Cal.
Pueblo, Colo.
Pyramid Peak, Cal.
Redding, Cal.
Rome, Ga.
Sacramento, Cal.
Scotts Bluff, Neb.
Silver City, Idaho.
Silverton, Colo.
Smartsville, Cal.
Sonora, Cal.
Spanish Peaks, Colo.
Telluride, Colo.
Tenmile District, Colo
Three Forks, Mont.
Tintic, Utah.
Truckee, Cal.
Uvalde, Texas.
Yellowstone, Wyo.

EXERCISE XIII

PLEISTOCENE AND RECENT

I. FOLIOS TO BE STUDIED

A. *Folios for More Elementary and Briefer Courses*

Aberdeen-Redfield, S. D.
Ann Arbor, Mich.
Beaver, Pa.
Brownsville–Connellsville, Pa.
Burgettstown-Carnegie, Pa.
Chicago, Ill.
Cloud Peak–Fort McKinney, Wyo.
Colfax, Cal.
Gaines, Pa.
Lancaster–Mineral Point, Wis.
Masontown-Uniontown, Pa.
New York City, N. Y.
Passaic, N. J.
Patoka, Ind.
Rockland, Me.
Sewickley, Pa.
Tacoma, Wash.
Warren, Pa.
Watkins Glen–Catatonk, N. Y.

B. *Additional Folios for More Advanced Courses*

Bismarck, N. D.
Casselton–Fargo, N. D.
Choptank, Md.
Claysville, Pa.
Dover, Del.
Elders Ridge, Pa.
Elk Point, S. D.
Ellensburg, Wash.
Engineer Mountain, Colo.
Foxburg–Clarion, Pa.
Flanklin Furnace, N. J.
Fredericksburg, Va.
Jamestown–Tower, N. D.
Latrobe, Pa.
Norfolk, Va.
Olivet, S. D.
Ouray, Colo.
Parker, S. D.
Patuxent, Md.
Philadelphia, Pa.
St. Marys, Md.
Trenton, N. J.
Waynesburg, Pa.

II. DIRECTIONS

Elementary Courses.—Study only the folios of Group A. Prepare answers to all questions not marked **, and answer in writing questions marked *.

Advanced Courses.—Study all the folios of A and B above, using those of Group B especially for answering the General Questions. Answer in writing questions marked * and **.

Note.—In this exercise, Surficial Geology sheets should be studied where they are found in the folios, and free use should be made of the folio texts.

III. QUESTIONS

Rockland Folio:

*1. What was the chief event of the Pleistocene period in this district, as shown by the character of the Pleistocene formations?

**2. What is the maximum relative change of level recorded in the Rockland quadrangle, since glaciation? (See the distribution of Qmc of the Surficial Geology map, and "Marine Clay," p. 5.)

New York City Folio:

1. Note the topographic expression of the Ptm belt on the Brooklyn and Staten Island sheets (Surficial Geology sheets).

*2. The origin of the plain of Psd across these quadrangles? Note its influence on the location of suburban towns.

3. Outline the Pleistocene history of this region.

Passaic Folio:

1. Study the Surficial Geology Sheet for various phases of glacial deposits.

*2. Account for the southward loop of Qtm east of the Watchung Mountains.

3. a) Note the distribution of Qk and Qdr.

**b) How would you distinguish between Qk and Qdr in the field?

Franklin Furnace Folio:

**1. Work out a plausible hypothesis for the origin of the areas of Qd north of Franklin Junction (central rectangle), east of Deckertown (north central rectangle), and near Northup (west central rectangle).

**2. Note the large kames, Qk, in the vicinity of Hamburg (east central rectangle), and the lesser kames in association with the other deltas, Qd. Has the association of kames and deltas any significance?

**3. Draw diagrams which shall illustrate the conditions under which the kame terraces of the quadrangle originated.

**4. Work out a hypothesis for the peculiar area of Qk at Ogdensburg. Note that it extends directly across a wide valley, except for the narrow gap through which the Wallkill River runs. This gap is probably post-glacial.

Watkins Glen–Catatonk Folio:

1. Note the distribution of Qtd. Were the present drainage lines of this area developed before, during, or after, the Wisconsin glacial epoch?

*2. Explain the origin of the broad flat north of Elmira and west of Horseheads, Watkins Glen quadrangle.

3. a) Note the location of eskers within and along stream valleys.

**b) What is the significance of this relation in connection with the origin of eskers?

Fredericksburg and Norfolk Folios:

*1. Interpret the Columbia formation, as shown in these folios.

Ann Arbor Folio:

**1. Correlate the several beach ridges with the successive lines of drainage from this area during the retreat of the Wisconsin ice sheet. (See pages 10 and 11 of the text.)

2. Note the location of this quadrangle with reference to the Saginaw and Huron-Erie ice lobes (Fig. 5, p. 4 of the text).

*3. Explain the abrupt constriction of the Huron valley at Dexter, nine miles northeast of Ann Arbor.

4. The origin of the band of Qgo and Qlc stretching from Ann Arbor southwest through Clinton and Tecumseh.

*5. Contrast the topography of this area with that of the Patoka and Gaines quadrangles. Explain the differences.

Patoka Folio:

*1. After a careful study of the legend, outline the Quaternary history of this region.

2. Does the formation Tr about two miles north of Princeton, have any significance with reference to the time limits within which the present relief was developed?

Chicago Folio:

**1. After a careful study of the topography, distribution, and character of the Pleistocene rocks, and the elevation and distribution of the shorelines, outline the glacial and post-glacial history of the region.

2. Account for the bowlder deposits in the northern part of the Desplaines quadrangle.

*3. History (date of origin, source of sand, etc.) of

the dunes east and south of Evergreen Park, Calumet quadrangle?

4. There are several outcrops of rock in the area covered by this folio. From this, and from the further fact that the drift is more than 100 feet deep at some points near the outcrops, what inference can be drawn as to the topography of the Niagara limestone?

Milwaukee Folio:

1. Note the various kinds of glacial deposits in the region.

2. What effect did the ice have on the drainage?

*3. In what ways might the outcrop of Dm along Milwaukee River 1 mile north of Milwaukee be explained? Which is the most probable explanation?

4. The meaning of the appearance of Dm at the quarry on the shore of Whitefish Bay?

**5. How could the character of the surface of the Paleozoic rocks in this region be ascertained?

Lancaster-Mineral Point Folio:

1. a) What part of this region was glaciated during the Pleistocene period?

b) During which glacial epoch was it glaciated?

*2. Account for the areal distribution of Ql (Lancaster quadrangle).

**3. Work out an explanation for the formation of the terraces, Qt, in the valleys tributary to the Mississippi.

Jamestown-Tower and Casselton-Fargo Folios:

1. What was the origin of the Qla formation? Of the Qd formation?

**2. Correlate the terrace deposits along Sheyenne River

(Casselton quadrangle) with successive stages of Lake Agassiz.

3. Note the section on p. 3, Casselton-Fargo folio.

**4. Work out the probable history of the bowlders in the Qb formation.

5. The source of the sand in the Qds formation?

Aberdeen-Redfield Folio:

1. Study the four Areal Geology sheets in the folio, for the general results of glaciation in the region.

2. Which of the Pleistocene ice sheets (early, late) affected the region?

3. Note the topographic expression of the Qam and Qld formations.

4. What is the meaning of the Qod formation?

Cloud Peak-Fort McKinney Folio:

1. Note the character and distribution of the Quaternary deposits.

2. Note the distribution of Ql, Cloud Peak Sheet, and explain its origin.

3. Give plausible hypotheses to explain the origin of Qt.

**4. a) What field evidence would you use to distinguish earlier glacial drift from later glacial drift?

b) How would you establish the age of Qvt, Cloud Peak Sheet?

Ouray and Engineer Mountain Folios:

**1. Discuss the map evidence for two periods of glaciation in this region.

2. Give some idea of the time that elapsed between the two epochs of glaciation.

Colfax Folio:

1. Estimate the amount of post-glacial cutting by the Yuba River near Emigrant Gap, northeast corner of central rectangle.

Ellensburg Folio:

**1. What is the origin of the Cowiche gravels?

Tacoma Folio:

*1. State plausible hypotheses for the origin of the broad depressions occupied by Puget Sound and tributary valleys.

General Questions

**1. How many epochs of glaciation are represented in Pennsylvania, as shown by the folios? Ditto in South Dakota? Ditto in Colorado?

**2. Work out an hypothesis which satisfactorily explains the constitution and distribution of the Carmichael formation, as shown in the western Pennsylvania folios.

**3. Outline the post-Miocene history of the Chesapeake and Delaware Bay region, as shown by the constitution, the stratigraphic relations, and the topographic distribution of the post-Miocene deposits. Both deposits and changes of level are to be considered. See especially the Trenton, Philadelphia, Dover, Patuxent, and St. Marys folios.

*4. Locate three clearly defined cases of drainage changes due to sheet glaciation.

**5. What, if any, products of economic value do the Pleistocene glacial deposits contain? Non-glacial?

6. How would you determine in the field whether a mountain valley had been glaciated?

*7. Make a list of non-glacial or only indirectly glacial Pleistocene deposits shown on the folios.

*8. What deposits of the Recent period are shown on the maps?

Many of the folios of the United States Geological Survey show deposits of Quaternary (Pleistocene and Recent) age, but a few of the more valuable ones for more extended work with these systems are listed below:

Absaroka, Wyo.
Alexandria, S. D.
Amity, Pa.
Anthracite-Crested Butte, Colo.
Bald Mountain-Dayton, Wyo.
Bidwell Bar, Cal.
Big Trees, Cal.
Danville, Ill.
De Smet, S. D.
Ditney, Ind.
Downieville, Cal.
Fort Benton, Mont.
Holyoke, Mass.
Huron, S. D.
Kittanning, Pa.
Lassen Peak, Cal.
Little Belt Mountains, Mont.
Livingston, Mont.
Mitchell, S. D.
Needle Mountains, Colo.
Nomini, Md.
Placerville, Cal.
Pyramid Peak, Cal.
Rogersville, Pa.
Rural Valley, Pa.
Silverton, Colo.
Snoqualmie, Wash.
Telluride, Colo.
Three Forks, Mont.
Tintic, Utah.
Truckee, Cal.
Washington, D. C.
Yellowstone, Wyo.

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